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LABORATORY EVALUATION OF A SAMPLE OF FUEL VAPOR DETECTORS FOR RECREATIONAL BOATS

WYLE LABORATORIES

PREPARED FOR

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The contents of this report reflect the views of Wyle Laboratories, Huntsville, Alabama, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Coast Guard. This report does not constitute a standard, specification, or regulation.

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ii

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16. Abstract

A survey was made to determine the commercially available fuel vapor detectors. From this survey a sample of five detectors were selected. The selection was made based upon cost, type of sensor and type of alarm. A Beckman Real-Time Hydrocarbon Analyzer was used in a method devised to experimentally establish the lower explosive limit (LEL) of a fuel (gasoline) and air mixture ranging from 0 to above 100 percent LEL. This set-up was then used to evaluate the sensitivity of each of the fuel vapor detectors prior to any testing. Each of the fuel vapor detector systems were subject to tests in temperatures ranging from -30°F to +150°F; humidity testing at 100°F and 95% relative humidity; shock tests at a level of 10 g in 15 milliseconds pulse duration; and finally, vibration testing to a random vibration spectrum established from open water tests on two outboard boats 15 and 18 feet in length. The vibration test levels, using the above established spectrum, were increased until failure occurred in all the units. Operational tests were performed at intervals throughout each of the test environments to establish whether or not the units were still functioning. The environments used were considered realistic except that of the four vibration levels only the first two or three were considered likely to exist in the normal boating environment. Of the five units tested only one could be considered adequate for their intended use; however, most of the units did indicate by either alarm or meter reading that a dangerous, if not explosive, situation existed. But the reliability or longevity was certainly in question if the units are in relatively small boats below 20 feet in length.

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Marine Safety Technology Division
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USCG Headquarters
Washington, D.C. 20590

FINAL REPORT

LABORATORY EVALUATION OF A SAMPLE OF FUEL VAPOR DETECTORS FOR RECREATIONAL BOATS

By

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October 1973

for

Work Performed Under Contract DOT-CG-12,377-A
Task Order 10

IV.

WYLE LABORATORIES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This report describes the performance testing and evaluation of five different commercially available fuel vapor detectors. All five instruments were subjected to temperature, humidity, shock, and vibration tests which simulated extreme working environments when installed in a small recreational boat. At the conclusion of each test a performance check was run to assess the effects of the test on the detector. Each detector was also inspected for any physical damage which would have an adverse effect upon its performance.

The performance check on each detector required exposure of the detector to known fuel vapor concentrations and noting the response of the detector. A test chamber was designed and built to provide measurable vapor concentrations with an operationally defined Lower Explosive Limit (LEL). The test chamber and associated equipment are described and their use discussed in more detail in Section 2.0.

Prior to subjecting the detectors to the test environments a performance test was given each instrument so that the performance changes throughout the program could be determined. In addition, vapor saturation tests were run to gain an idea of the recovery characteristics of the detectors. These tests and results are described in Section 3.0.

The response of the detectors after undergoing temperatures of $-30^{\circ}F$ and $0^{\circ}F$ are given in Section 4.1 and the responses after being subjected to $150^{\circ}F$ are described in Section 4.2. The humidity testing at $100^{\circ}F$ and 95% relative humidity is described in Section 5.0, the shock testing in Section 6.0 and the vibration testing in Section 7.0.

In general, the vapor detectors on the market must be construed to be less than adequate in <u>extreme</u> recreational boat environments. Of the five units tested only one could be deemed acceptable. The environment causing most damage was the vibration environment. However, no claim can be made that the environment is representative for any other than relatively small boats (up to about 18 feet) since no data is available. It <u>can</u> be stated that the environment used is quite severe at levels above the lowest used in vibration.

2.0 VAPOR DETECTORS AND VAPOR TEST CHAMBER

2.1 Vapor Detectors

From an initial market survey[1], a total of five different vapor detectors were chosen as being representative examples of the commercially available models with respect to type of sensor and type of alarm. The specific detectors used are shown in Figures 1 through 5 with their relevant characteristics listed in Table I.

Each vapor detector was given a test specimen number for ease in referencing and to eliminate manufacturer name in analyzing the test results. Each detector will be referred to only by its assigned specimen number.

2.2 Test Chamber and Calibration

A 2' x 2' x 2' vapor test chamber shown in the photograph in Figure 6 was constructed to provide the necessary vapor concentrations for the operational tests. The front panel was made from 1/4" thick plexiglass and contained a door for easy access into the chamber. The other three sides were constructed of 5 mil thick polyvinyl ethelene and supported by a steel rod frame. The floor of the chamber was plywood while the top was a loosely fitted lid made of styrofoam and covered inside and outside with duck tape. The lid acted as a safety valve whenever an explosion took place as described below.

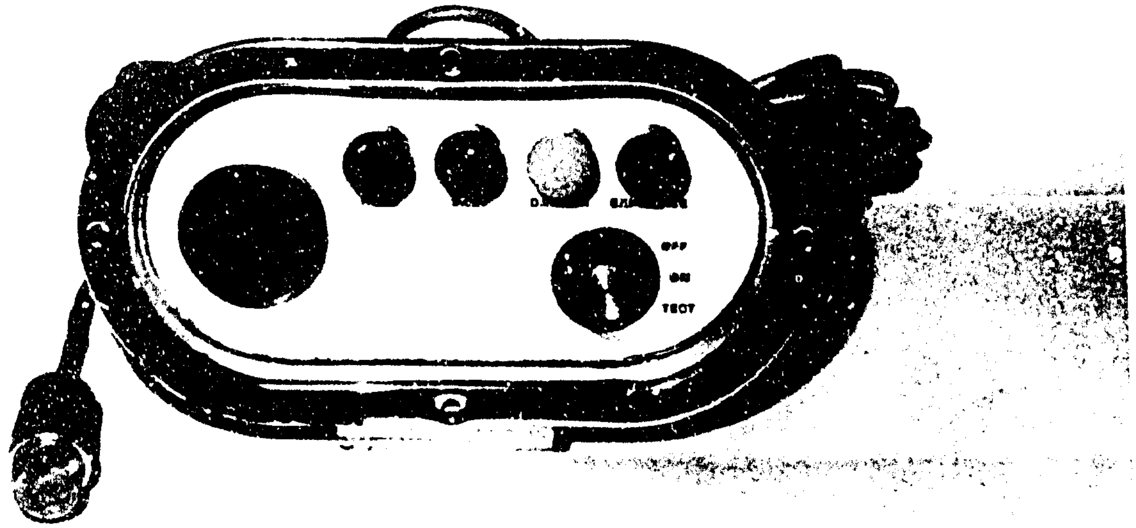
The fuel vapor was introduced into the chamber by the simple expedient of heating a measured amount of gasoline in a small steel dish and allowing it to vaporize. Heat was supplied by a hot plate. A small fan circulated the vapor throughout the chamber. The gasoline used was from a single drum. A sample was analyzed by Phoenix Chemical Laboratory, Inc., and was determined to have a vapor density of 2.44 grams/liter at 100°F and an average molecular weight of 103.

The vapor concentration in the test chamber was measured by a Beckman Model 400 Hydrocarbon Analyzer. The analyzer used 39.5, 39.6 and 39.7% hydrogen as fuel (the balance was helium). A bottled air supply was used containing less than 0.2 molar ppm impurities. All concentrations were determined by Air Products and Chemicals, Inc. All tubing used in

TABLE I. VAPOR DETECTORS AND OPERATIONAL CHARACTERISTICS

Manufacturer *	Model *	Test Designation	Operation Characteristics
		VD-1	Hot wire sensor. Has self-test. Indicates by alarm and lights. Blue for warmup, green for safe, amber for danger, and red for explosive. Alarm sounds when amber light is on and rises to louder level when red light is on. Self test runs through lights and alarm sequence in the order of explosive to safe.
		VD-2	Cold absorptive sensor. Has self-test. Indicate vapor level by alarm intensity only. Self-test causes alarm to sound.
		VD-3	Hot wire sensor. Has self-test. Indicates by meter and alarm. Meter divided into "safe," "dangerous," and "explosive" zones. Alarm sounds when "explosive" condition exists. Self-test indicates "explosive" condition with both meter and alarm.
		VD-4	Cold absorptive sensor. Self-test and operation same as for VD-3. Has zero adjustment.
		VD-5	Hot wire sensor. Indicates by meter divided into "safe," "dangerous," and "explosive" zones. Has zero adjustment.

* Intentionally left blank - supplied under separate cover.



VD-1

Figure 1. Fuel Vapor Detector Sample No. 1

Figure 2. Fuel Vapor Detector Sample No. 2

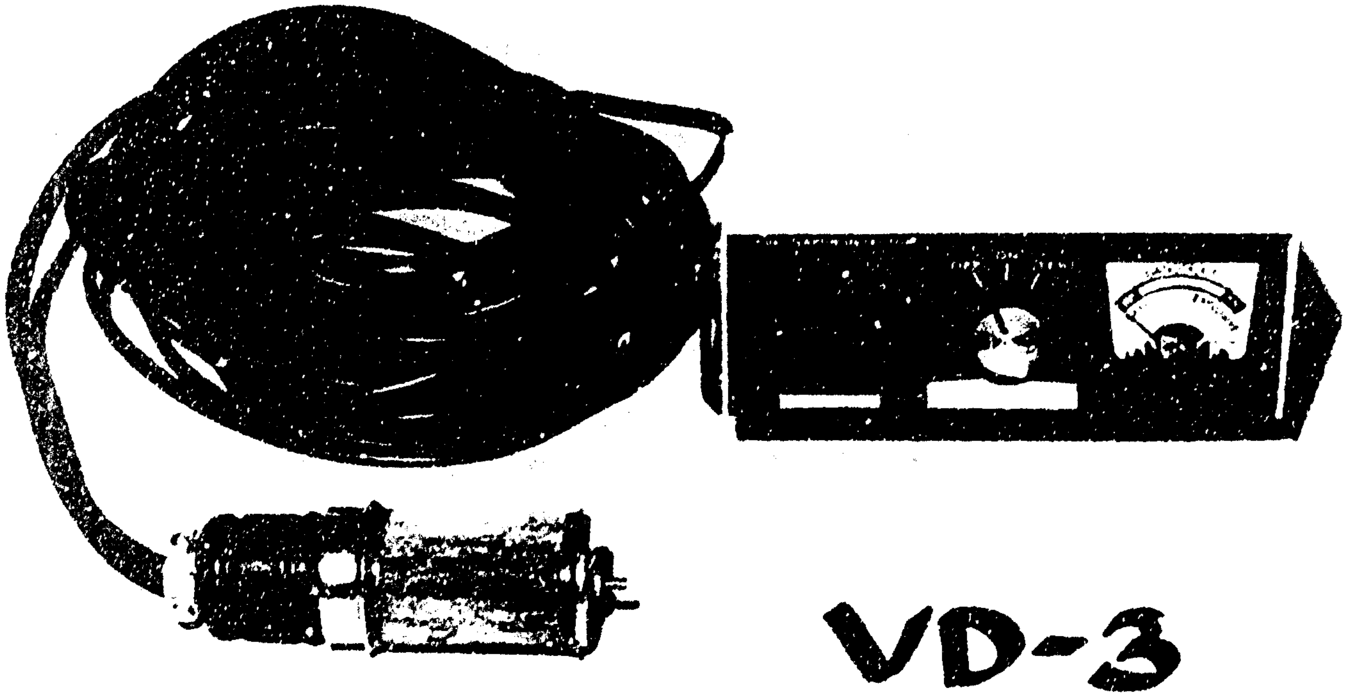


Figure 3. Fuel Vapor Detector Sample No. 3

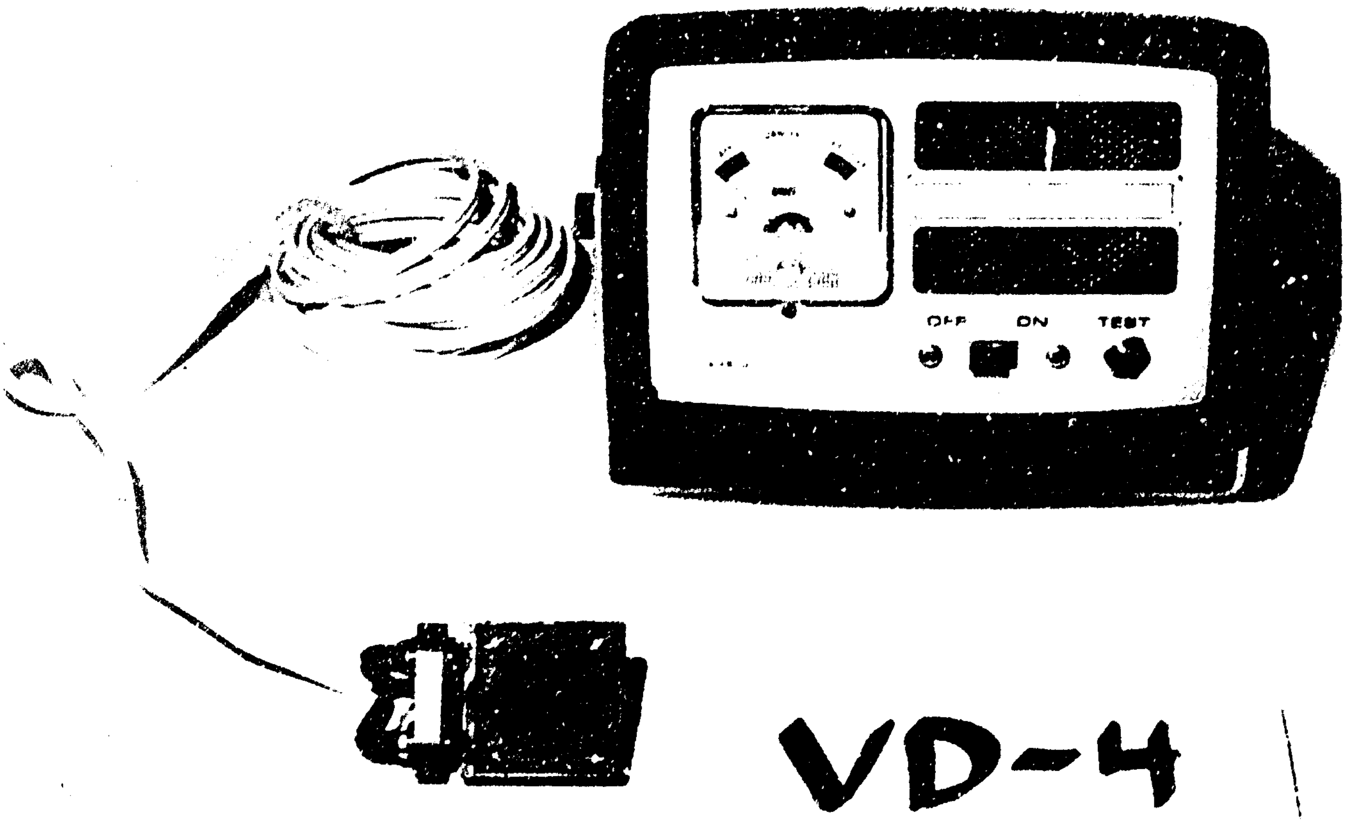
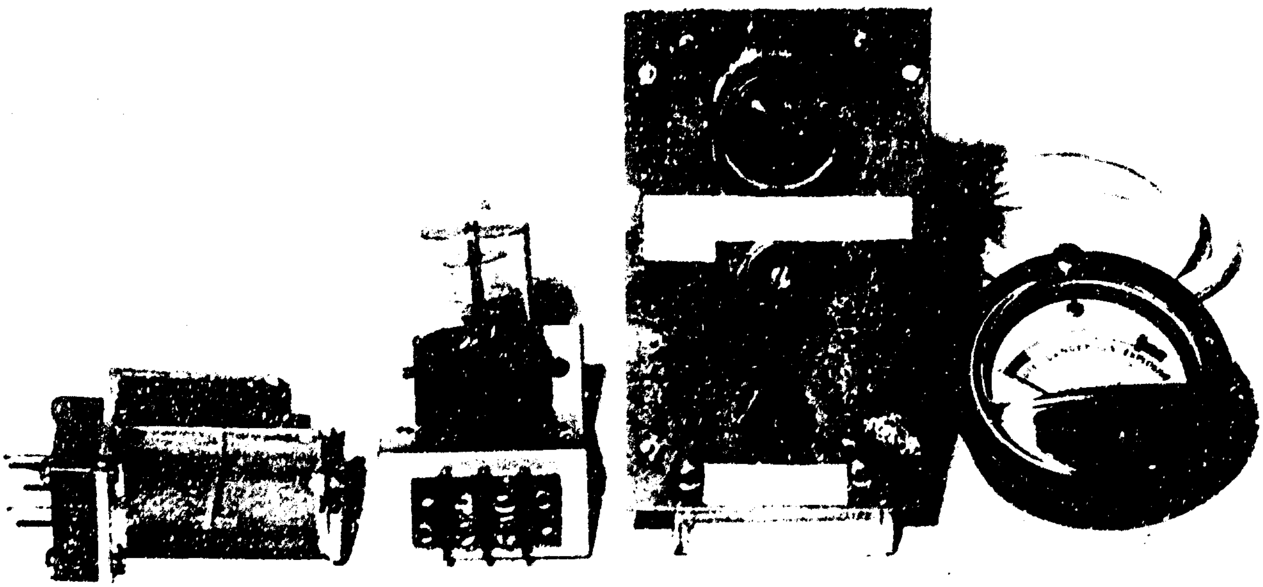


Figure 4. Fuel Vapor Detector Sample No. 4



VD-5

Figure 5. Fuel Vapor Detector Sample No. 5

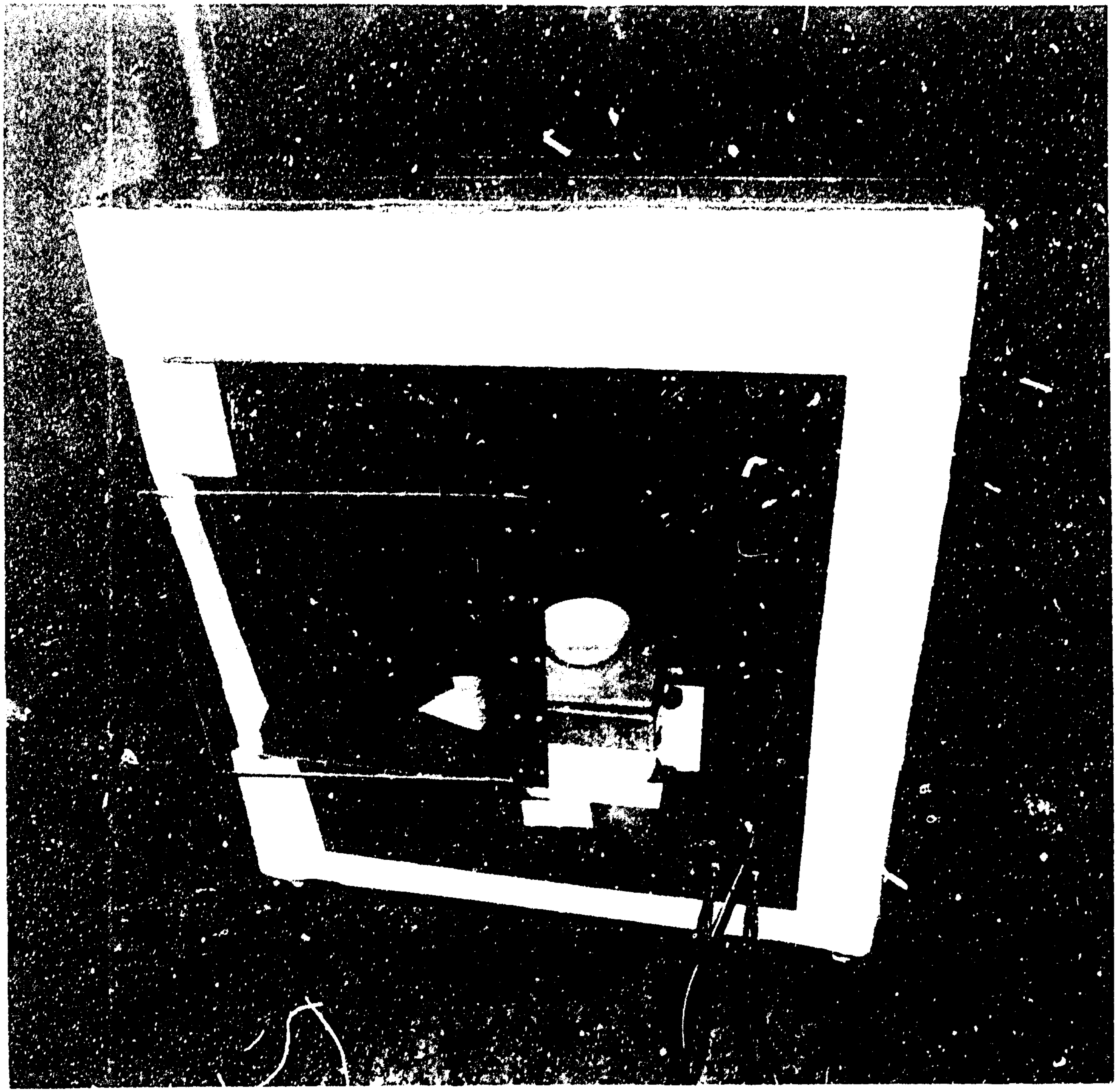


Figure 6. Photograph of Vapor Test Chamber

connection with the Beckman Analyzer was copper refrigeration tubing. The response time of the analyzer was found to be approximately 20 seconds which was the time necessary for the sampled gas to be pulled into the flame unit.

A spark circuit was provided to operationally define the LEL inside the chamber. The Beckman Analyzer could then be calibrated by setting any point on the linear scale to correspond to the LEL. The spark gap was placed in close proximity to the sample tube end inside the chamber so that the vapor levels at the spark gap and the sample tube would correspond closely. Figure 7 shows a schematic of the test chamber and supporting equipment.

3.0 INITIAL OPERATION AND SATURATION TESTS

3.1 Initial Operation Tests

Before subjugation to any testing, the operating characteristics of each detector was determined by installing the sensor head into the test chamber, vaporizing 30 ml of gasoline, and noting the detector response to vapor concentration in % LEL as given by the Beckman Analyzer. Readings were taken both as the vapor concentration increased and then as it decreased after the vaporization of the gasoline was completed. Tables II, III, IV, V, and VI give the results for these operating tests.

3.2 Vapor Saturation of Detectors

The purpose of this test was to determine the operating response and recovery time for each detector. Thirty (30) ml of gasoline were put into a steel beaker and the beaker was then placed upon the hot plate to vaporize the gasoline. The sensor of each detector and the sampling tube of the Beckman Analyzer were then lowered into the vapor for 30 seconds. The highest readings of both the Beckman Analyzer and the detector were noted and also the time needed by the detector to reach its highest reading after immersion in the vapor. After the 30 second immersion the detector sensor was removed from the vicinity of the vapor and the time required for the detector to return to a "safe" reading was recorded. The results of this test are given in Table VII.

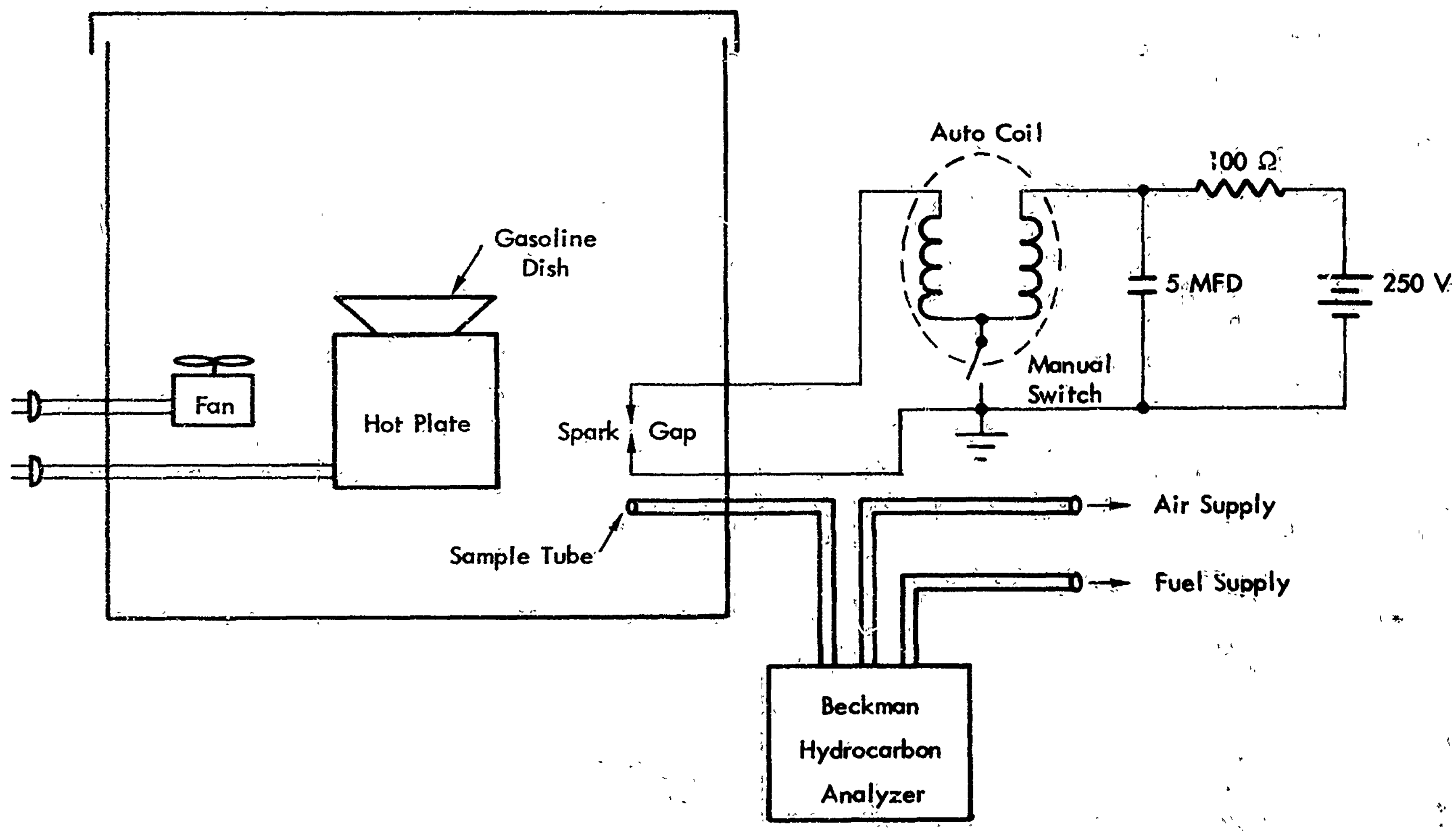


Figure 7. Vapor Test Chamber Schematic

TABLE II. RESPONSE OF VD-1 TO VAPOR CONCENTRATION

	% LEL Range	Detector Response
Increasing Vapor Conc.	0 → 25	Green "safe" light on, Alarm silent
	25 → 100	Amber "danger" light on, Alarm on
Decreasing Vapor Conc.	100 → 50	Amber "danger" light on, Alarm on
	50 - 40	Dim green "safe" light, dim amber "danger" light, Alarm on
	40 - 30	Dim green "safe" light, dim amber "danger" light Alarm silent
	30 → 0	Green "safe" light on, Alarm silent

TABLE III. RESPONSE OF VD-2 TO VAPOR CONCENTRATION

	% LEL Range	Detector Response
Increasing Vapor Conc	0 → 80	Alarm silent
	80 → 100	Alarm on and growing louder as concentration increases
Decreasing Vapor Conc.	100 → 2	Alarm on and growing fainter as concentration decreases
	2 → 0	Alarm silent

TABLE IV. RESPONSE OF VD-3 TO VAPOR CONCENTRATION

	% LEL Range	Detector Response
Increasing Vapor Conc.	0 → 60	Meter indicates "safe," alarm silent
	60 → 80	Meter indicates "safe," alarm on
	80 → 100	Meter indicates "dangerous," alarm on
Decreasing Vapor Conc.	100 → 80	Meter indicates "dangerous," alarm on
	80 → 65	Meter indicates "safe," alarm on
	65 → 0	Meter indicates "safe," alarm off

TABLE V. RESPONSE OF VD-4 TO VAPOR CONCENTRATION

	% LEL Range	Detector Response
Increasing Vapor Concentration	0 → 20	Meter indicates "safe," alarm silent
	20 → 60	Meter indicates "danger," alarm silent
	60 → 85	Meter indicates "danger," alarm on and growing louder as vapor concentration increases
	85 → 100	Meter indicates "explosive," alarm on and growing louder as vapor concentration increases
Decreasing Vapor Concentration	100 → 20	Meter indicates "explosive," alarm on and growing fainter as vapor concentration decreases
	20 → 4	Meter indicates "danger," alarm on and growing fainter as vapor concentration decreases
	4 → 0	Meter indicates "danger," alarm silent

TABLE VI. RESPONSE OF VD-5 TO VAPOR CONCENTRATION

	% LEL Range	Detector Response
Increasing Vapor Conc.	0 → 5	Meter indicates "safe"
	5 → 65	Meter indicates "danger"
	65 → 00	Meter indicates "explosive," meter reads full scale at 90% and is hard on stop at 100%
Decreasing Vapor Conc.	100 → 80	Meter indicates "explosive," meter reads full scale at 90% and is hard on stop at 100%
	80 → 10	Meter indicates "danger"
	10 → 0	Meter indicates "safe"

TABLE VII. INITIAL VAPOR SATURATION SENSING AND RECOVERY TIMES

Specimen	% LEL	Sensing Time (sec)	Recovery Time (minutes)		
			Meter	Light(s)	Alarm
VD-1	500	3	-	1.5	3.5
VD-2	500	3	-	-	6.5
VD-3	500	*	1.0	-	3.0
VD-4	800	1	38.0	-	6.5
VD-5	400	13	6.0	-	-

* Response not fast enough to indicate an explosive condition. Does not indicate until sensor is placed in fresh air.

4.0 LOW AND HIGH TEMPERATURE TESTS

4.1 Low Temperature Test and Results

This test was designed to test the performance of the vapor detectors after having been exposed to low temperatures. The vapor detectors with sensors were placed in a Conrad Temperature Chamber (see Figure 8) and subjected to a chamber ambient temperature of -30°F for 24 hours. After this period of time the chamber temperature was raised to 0°F and kept at this higher temperature for four hours.

After the exposure to the low temperatures the detectors were removed from the temperature chamber and given the operational test described in Section 3.1 for increasing vapor concentrations only. The results are given in Table VIII. Two sensors were used to test VD-3 since the first sensor always gave a meter reading of safe for all vapor levels. The new sensing unit was left for later tests. A new sensor was also tried on VD-4 since it gave an initial meter reading of danger but the new sensor did not change the reading. The unit was therefore tested with the old sensor. VD-4 had a zero adjustment but for purposes of testing it was not adjusted.

4.2 High Temperature Test and Results

After the operational tests were concluded for the low temperature tests the vapor detectors with attached sensors were replaced in the temperature chamber and subjected to a chamber ambient temperature of 150°F for four hours. The vapor detectors were then removed from the chamber, allowed to cool to ambient temperatures, and operationally tested again. The results of this test are given in Table IX.

5.0 HUMIDITY TEST

The humidity test was conducted by placing the vapor detectors with sensors attached into a Wyle humidity chamber and subjecting the detectors to a chamber ambient temperature 100°F and 95% relative humidity for a period of ten days. At the end of this period the detectors were first given vapor saturation tests and then removed from the chamber and tested operationally for increasing vapor concentrations.

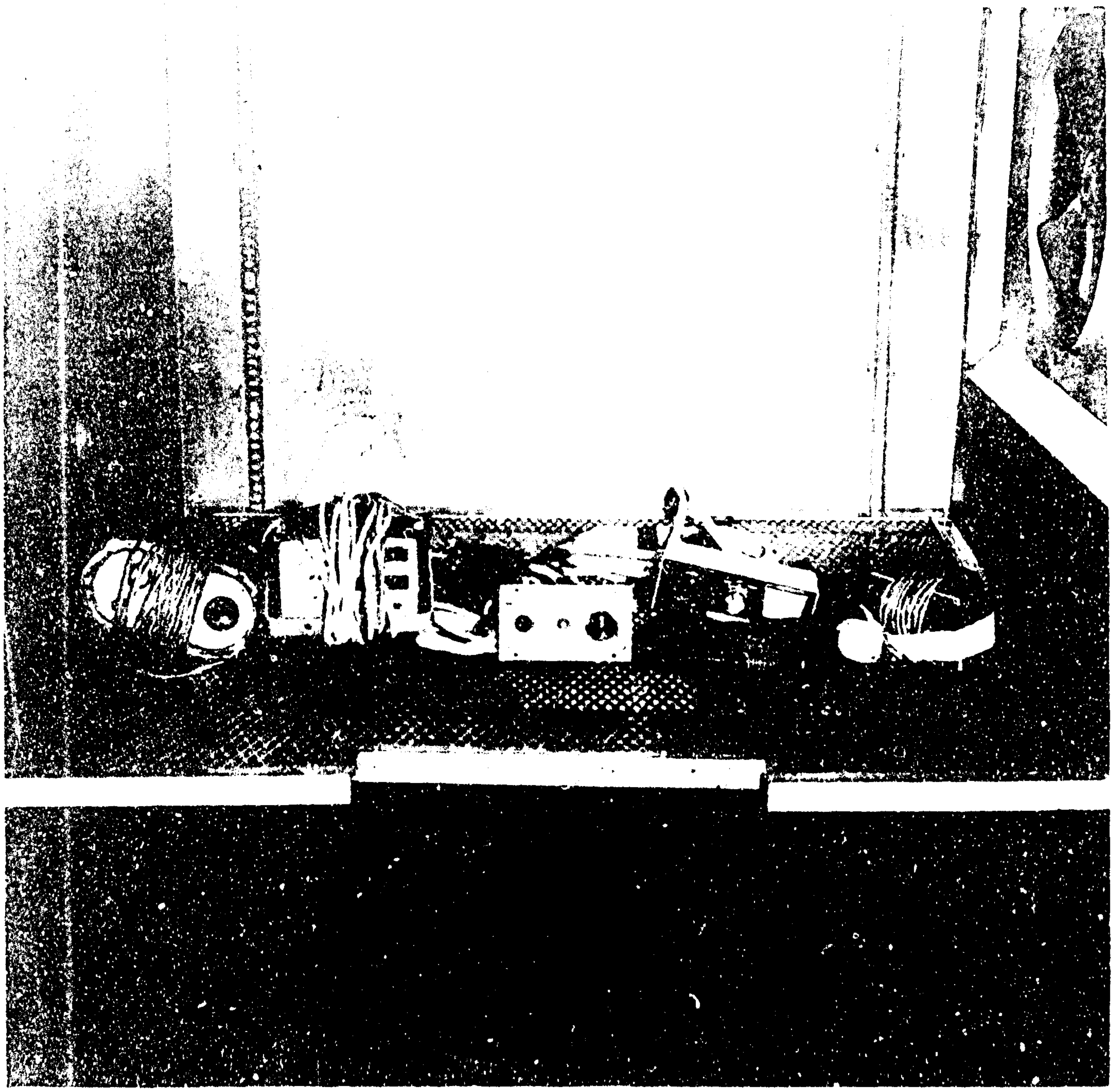


Figure 8. Conrad Temperature Chamber

TABLE VIII. DETECTOR RESPONSE AFTER 24 HOUR EXPOSURE TO $-30^\circ F$ AND 4 HOUR EXPOSURE TO $0^\circ F$ TEMPERATURES

Specimen	% LEL Range	Detector Response[1]
VD-1	0 → 5	Green "safe" light on, alarm silent
	5 → 10	Green "safe" light on, alarm on
	10 → 45	Amber "danger" light on, alarm on
	45 → 60	Amber "danger" and red "explosive" lights on, alarm on
	60 → 100	Red "explosive" light on, alarm on
VD-2[2]	0 → 65	Alarm silent
	65 → 100	Alarm on, growing louder as vapor level increases
VD-3, Sensor 1	0 → 90	Meter reads "safe," alarm silent
	90 → 100	Meter reads "safe," alarm on
VD-3, Sensor 2	0 → 40	Meter reads "safe," alarm silent
	40 → 60	Meter reads "safe," alarm on
	60 → 100	Meter reads "danger," increasing to mid-scale danger at 100% LEL, alarm on
VD-4	0 → 60	Meter reading increases from 1/4 scale "danger" at 0% LEL to mid-scale danger
	60 → 100	Meter reads "danger," alarm on at low level and changing to loud at 65% LEL
VD-5	0 → 10	Meter reads "safe"
	10 → 60	Meter reads "danger," increasing to 3/4 "danger" at 45% LEL
	60 → 100	Meter reads "explosive" and reading full scale at 80% LEL and going off scale at 90% LEL

1 All self-tests performed correctly

2 Terminal strip found loose from cage

TABLE IX. DETECTOR RESPONSE AFTER FOUR HOUR EXPOSURE TO 150°F

Specimen	% LEL Range	Detector Response [1]
VD-1	0 → 5 5 → 30 30 → 100	Green "safe" light on. Alarm silent Green "safe" light and amber "danger" lights on, alarm on Amber "danger" light on, alarm on
VD-2	0 → 75 75 → 100	Alarm silent Alarm on growing louder as vapor concentration increases
VD-3 [2]	0 → 65 65 → 75 75 → 130	Meter reads "safe," alarm silent Meter reads "safe," alarm on Meter reads "danger" increasing to mid-scale danger at 95% LEL. At 100% LEL meter begins to oscillate, does not indicate "explosive" until 130% LEL.
VD-4	0 → 15 15 → 130	Meter reads "safe," alarm silent Meter reads "danger" increasing to mid-scale at 130% LEL. Alarm does not sound until 130% LEL is reached.
VD-5	0 → 5 5 → 55 55 → 100	Meter reads "safe" Meter reads "danger" with mid-scale danger occurring at 20% LEL. Meter reads "explosive" increasing to full scale "explosive" at 70% LEL and going off scale at 80% LEL.

1 All self-tests performed correctly

2 When unit was set to test while indicating danger, meter indicated safe when reset to on.

TABLE X. DETECTOR RESPONSES AFTER 10 DAY EXPOSURE TO 100°F AND 95% RELATIVE HUMIDITY

Specimen	% LEL Range	Detector Response [1]
VD-1	0 → 10 10 → 100	Green "safe" light on, alarm silent Amber "danger" light on, alarm on
VD-2 Sensor 1	0 → 90 90 → 100	Alarm silent Alarm on, low at 90% LEL increasing to loud at 100% LEL.
VD-2 Sensor 2	0 → 10 10 → 100	Alarm silent Alarm on, low at 10% LEL increasing to loud at 100% LEL.
VD-3	0 → 5 5 → 60 60 → 100	Meter reads "safe," alarm silent Meter reads "safe," alarm on Meter reads "danger" increasing to mid-scale "danger" at 80% LEL and to 3/4 scale "danger" at 100% LEL. Alarm on
VD-4 Sensor 1	0 → 90 90 → 100	Meter reads "danger," alarm silent Meter reads "danger," alarm on
VD-4 Sensor 2	0 → 10 10 → 65 65 → 100	Meter reads "danger," alarm silent Meter reads "danger," alarm on Meter reads "explosive," alarm on
VD-5	0 → 10 10 → 80 80 → 100	Meter reads "safe" Meter reads "danger" with mid-scale "danger" occurring at 40% LEL. Meter reads "explosive"

1 All self-tests performed correctly

The vapor saturation test consisted of holding a gas soaked cloth next to the sensor and observing whether or not the detector registered an explosive atmosphere. Detectors VD-1, VD-3, VD-4, and VD-5 indicated an explosive atmosphere but VD-2 had a very slow response and a low alarm level. The results of these operational tests are summarized in Table X.

As seen from Table X, both VD-2 and VD-4 were tested with two sensing units since the operational tests with the original sensors showed rather poor behavior. The new sensors were left installed for succeeding tests.

Each detector was inspected for physical damage. A slight amount of corrosion was observed on the light bulb holders in VD-1 but no other damage was found. This corrosion would not seem great enough to impair the operation of the detector.

6.0 SHOCK TEST

The criteria for shock testing was taken from the Fuel Systems Standards Analysis Development Report [2] prepared for the United States Coast Guard by Wyle Laboratories. Based upon the discussion contained in Appendix F, Section 2.8 of this report, a shock cycle of 10 g amplitude and 15 milliseconds duration was chosen. The oscilloscope trace of this shock cycle is shown in Figure 9 and the instrumentation equipment, data, and log sheets for both the shock and vibration tests are found in the Appendix.

The vapor detectors together with their sensor elements were mounted on the shaker head (the exciting fixture) in their normal installation configuration and then were subjected to a total of 1,000 consecutive shock cycles (see Figure 10). The fuel detectors were left running during the test and were given a vapor saturation test at the end of every 250 cycles.

The saturation test for the detectors for both the shock and vibration (see Section 7.0) testing consisted of holding a gasoline soaked cloth next to the sensor element and noting the response of the detector. The instrument was judged "acceptable" if it indicated an explosive environment. Table XI summarizes the results of the vapor saturation tests.

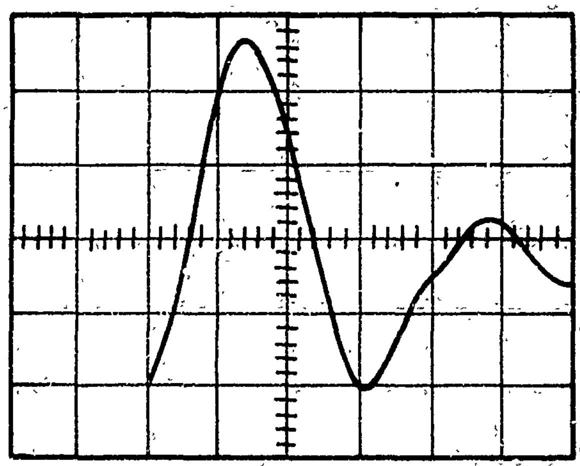


Figure 9. Oscilloscope Trace of Shock Cycle

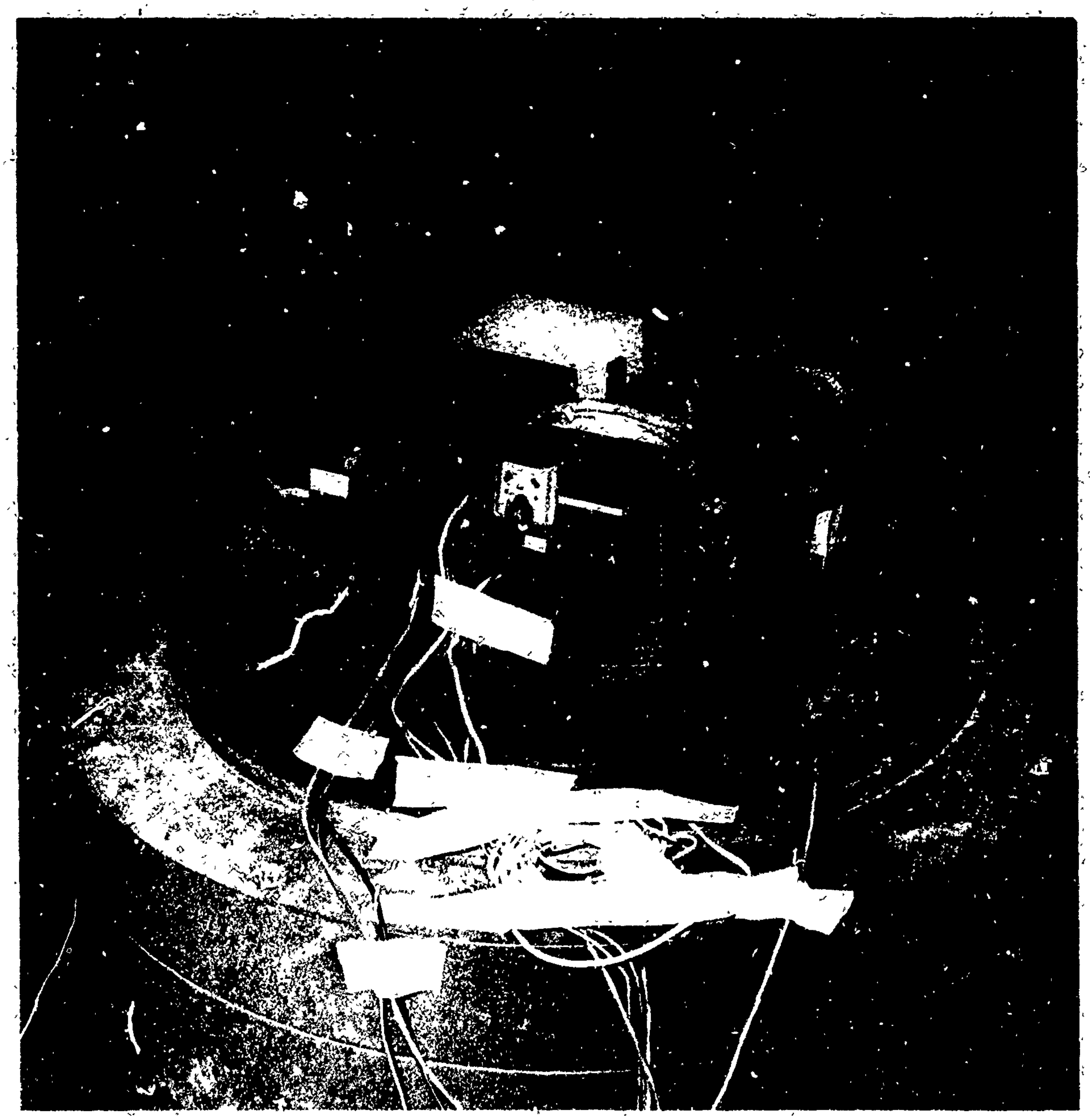


Figure 10. Test Set-up for Both Shock and Vibration Testing

TABLE XI. DETECTOR SATURATION TEST RESPONSES AFTER SHOCK TESTING

Number of Shock Cycles	Specimen	Detector Response and Condition
250	VD-1	Saturation test - o.k.
	VD-2	Saturation test - o.k.
	VD-3	Saturation test - o.k.
	VD-4	Showed "danger" initially - saturation test - o.k.
	VD-5	Saturation test - o.k.
500	VD-1	Saturation test - o.k.
	VD-2	Saturation test - o.k.
	VD-3	Would not indicate vapor with meter or alarm
	VD-4	Alarm sounded intermittently, would not stop
	VD-5	Saturation test - o.k.
750	VD-1	Saturation test - o.k.
	VD-2	Saturation test - o.k.
	VD-3	Would not indicate vapor with meter or alarm
	VD-4	Indicates danger
	VD-5	Saturation test - o.k.
1000	VD-1	Saturation test - o.k.
	VD-2	Would not indicate
	VD-3	When gas-soaked cloth held close to sensor meter went to mid-scale "danger," the alarm sounded. Alarm went silent and meter returned to safe before cloth was removed. Loose connection was found and repaired.
	VD-4	Saturation test - o.k.
	VD-5	Saturation test - o.k.

7.0 VIBRATION TEST

A problem arose in connection with the vibration testing since there appeared to be no accepted criteria for determining a realistic vibration spectrum or level. To overcome this obstacle four time histories of accelerometer data were taken under actual running conditions as described below.

Two outboard boats, a Winner 18 ft with a 130 HP engine and a Glastron GT 15 ft with a 85 HP engine, were driven full speed in rough water each with an accelerometer mounted in the stern and an accelerometer mounted in the bow. An analog tape recorder was used to record the time histories provided by the four accelerometers. Only vertical acceleration was recorded. The water was rough enough that it was concluded that no normal boat owner would have driven his boat at full speed due to extreme discomfort.

From each of these four time histories a Power Spectral Density (PSD) was obtained which was used to select PSD's for testing the vapor detectors. The four PSD's are shown in Figure 11 and the selected test PSD shape in Figure 12. This PSD spectrum was used for four different vibration tests each test having a different level at 10 Hz. The levels at 10 Hz chosen for testing were $0.01 g^2/Hz$, $0.03 g^3/Hz$, $0.1 g^2/Hz$, $0.1 g^3/Hz$, and $0.3 g^2/Hz$, where g is the gravitational acceleration, $32.2 ft/sec^2$. The increasing levels were selected to determine the level at which failure would occur.

The five vapor detectors together with their sensor heads were mounted on the shaker head in their operational configuration and in their fully-operating modes. Each of the first three vibration tests were run for one hour while the highest level test was run until failure occurred. Figures 13 through 16 give the actual PSD's recorded at the shaker head at the start of each test. The acceleration rms values for each test are given in Table XII.

After each vibration test the detectors were subjected to the same vapor saturation test as they were following the shock testing. The results are summarized in Table XII. As can be seen, none of the detectors survived the total planned vibration testing. As soon as a detector was found to have failed, it was removed from any further vibrational testing.

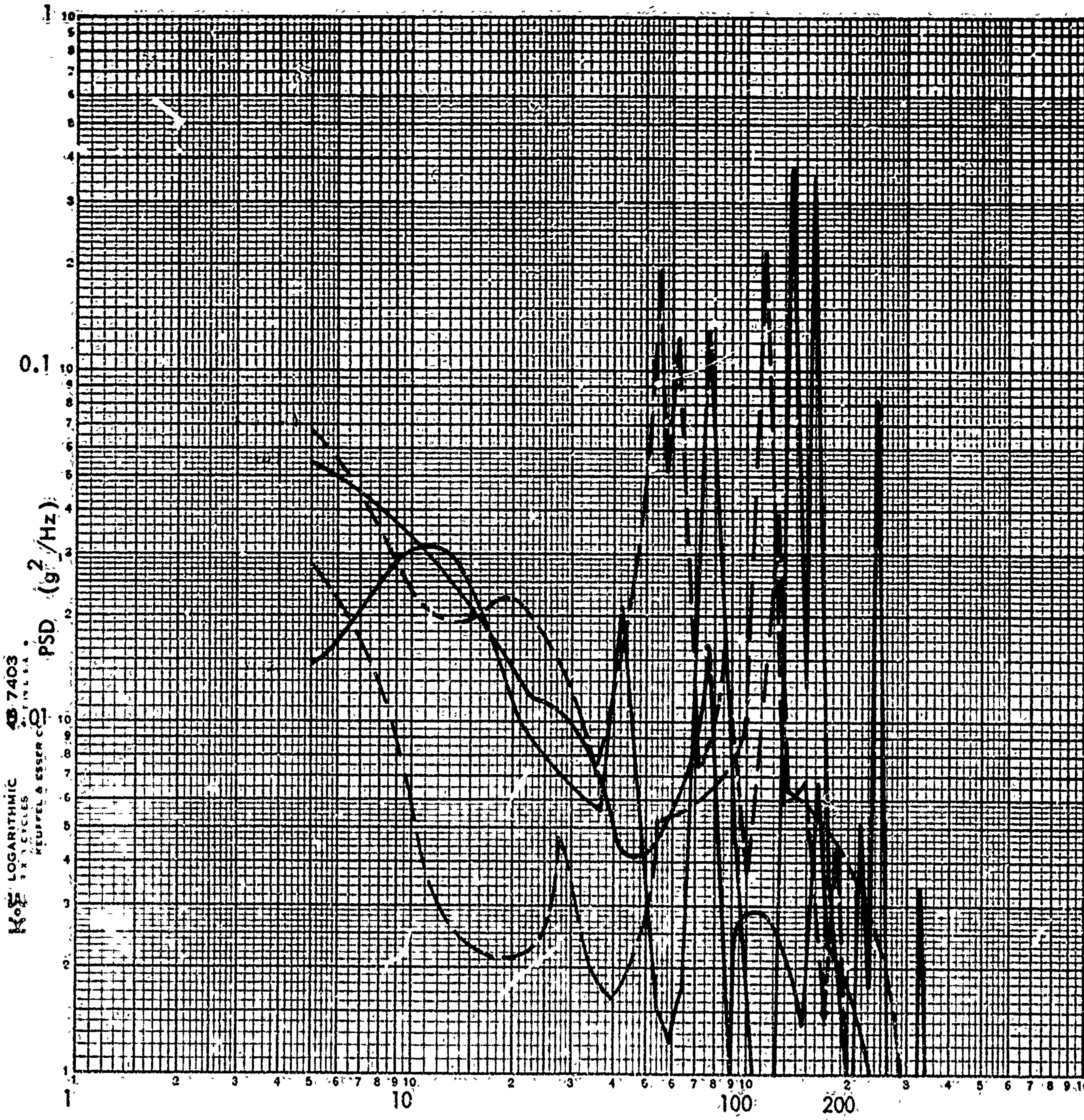
FULL SCALE LEVEL (g^2/Hz)

J/N

Page

Date

.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐



CUSTOMER

SPECIMEN

S/N

AXIS

LOCATION NO.

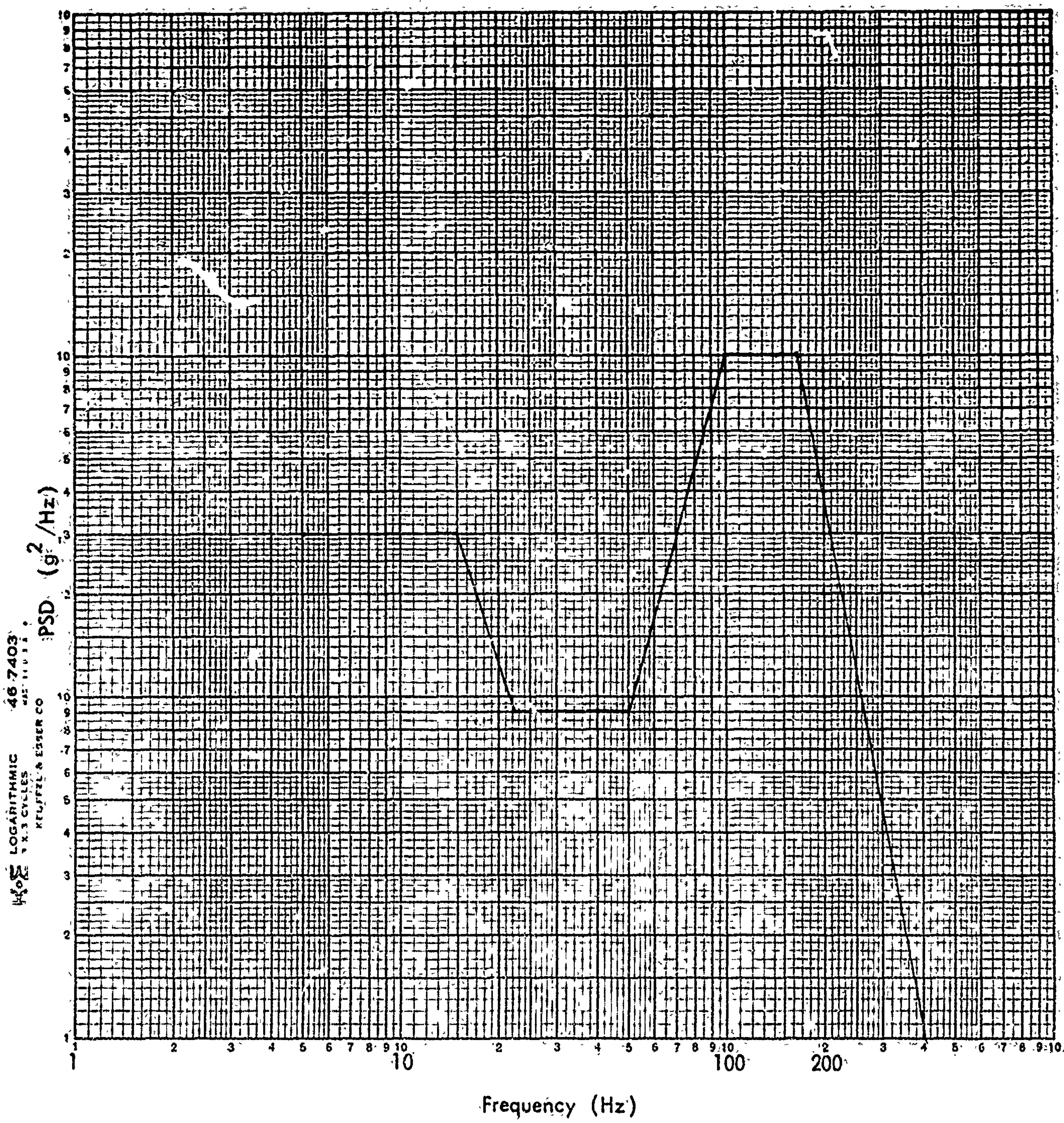
TEST RUN NO.

Figure 11. Power Spectral Densities from Outboard Boats

FULL SCALE LEVEL (g^2 / Hz)

J/N ____________
Page ____________
Date ____________

.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐



CUSTOMER ____________ AXIS ____________

SPECIMEN ____________ LOCATION NO. ____________

S/N ____________ TEST RUN NO. ____________

Figure 12. Required Vibration Test Spectrum Shape

FULL SCALE LEVEL (g^2 / Hz)

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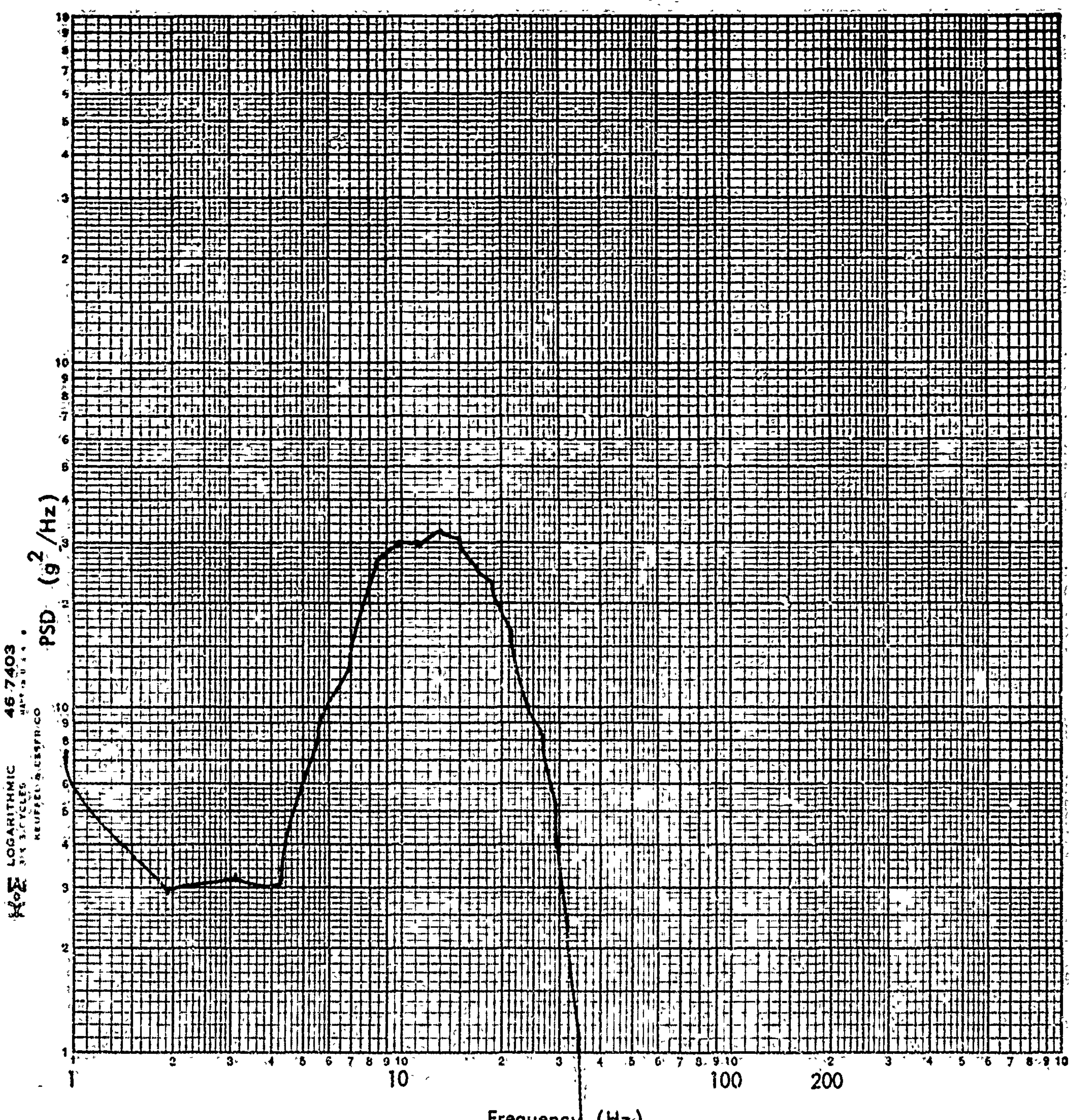
.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐



CUSTOMER USCG

AXIS VERT

SPECIMEN FUEL VAPOR DETECTOR

LOCATION NO. CONTROL

S/N

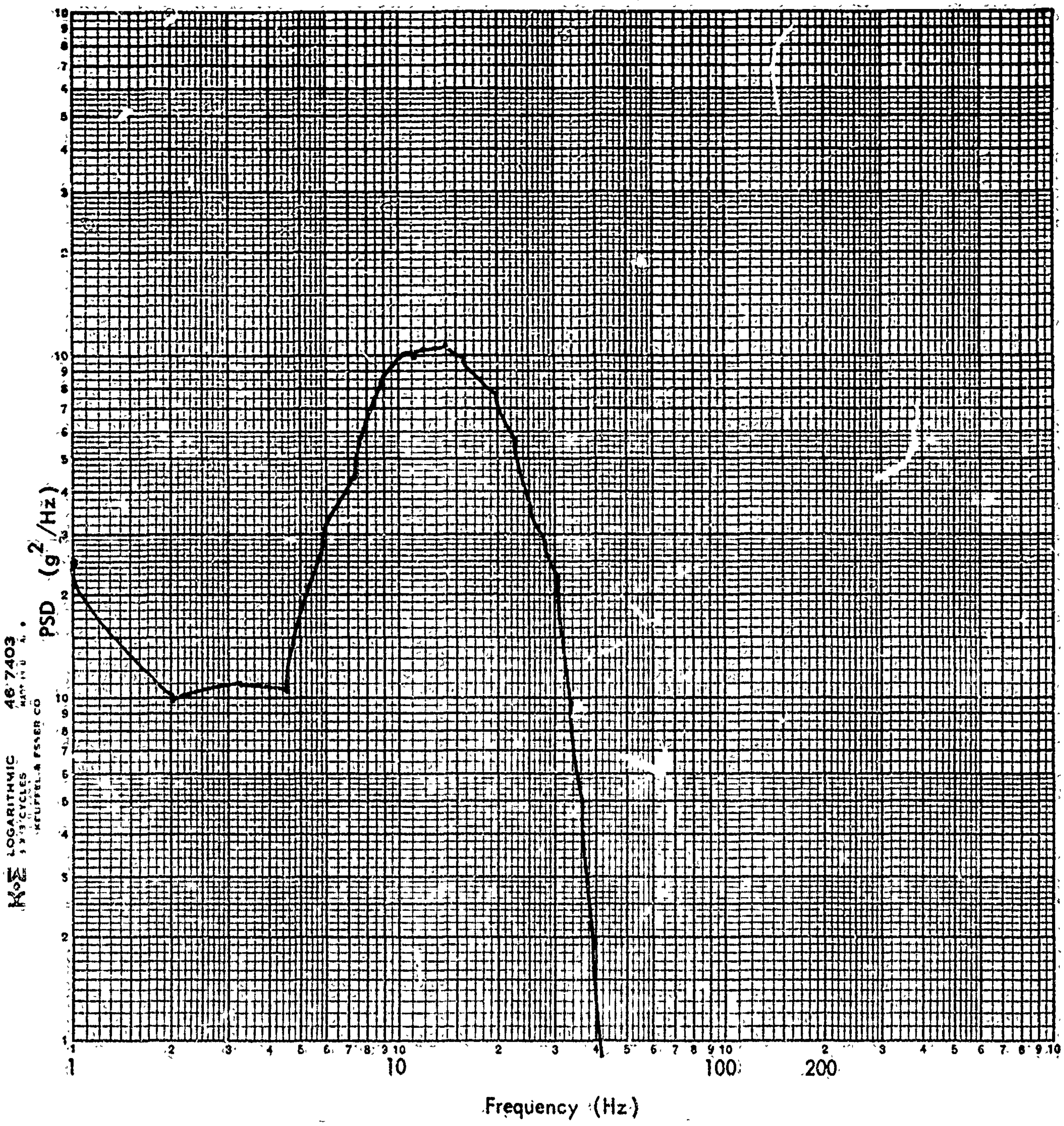
TEST RUN NO. 1 START

Figure 13. Power Density Spectrum for 0.01 g^2/Hz Level Testing

FULL SCALE LEVEL (g^2/Hz)

.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐

J/N 65210
Page
Date 6-8-73



CUSTOMER USCG AXIS Vert

SPECIMEN Fuel Vapor Detector LOCATION NO. CONTROL

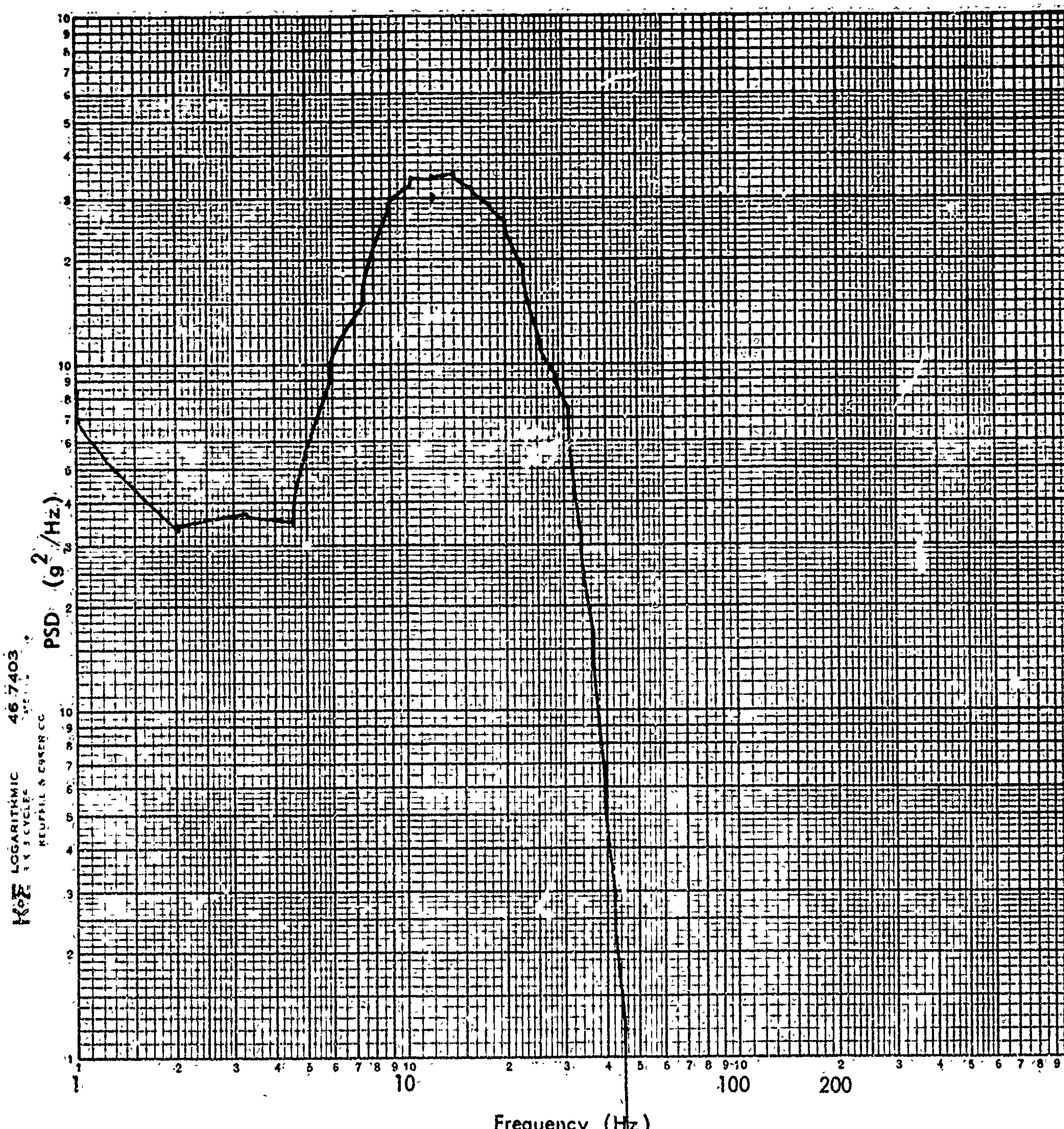
S/N ______ TEST RUN NO. 2 START

Figure 14. Power Density Spectrum for 0.03 g^2/Hz Level Testing

FULL SCALE LEVEL (g^2 / Hz)

J/N 58816
Page
Date 6-8-73

.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐



CUSTOMER USCG

AXIS VERT

SPECIMEN FUEL VAPOR DETECTOR

LOCATION NO. CONTROL

S/N

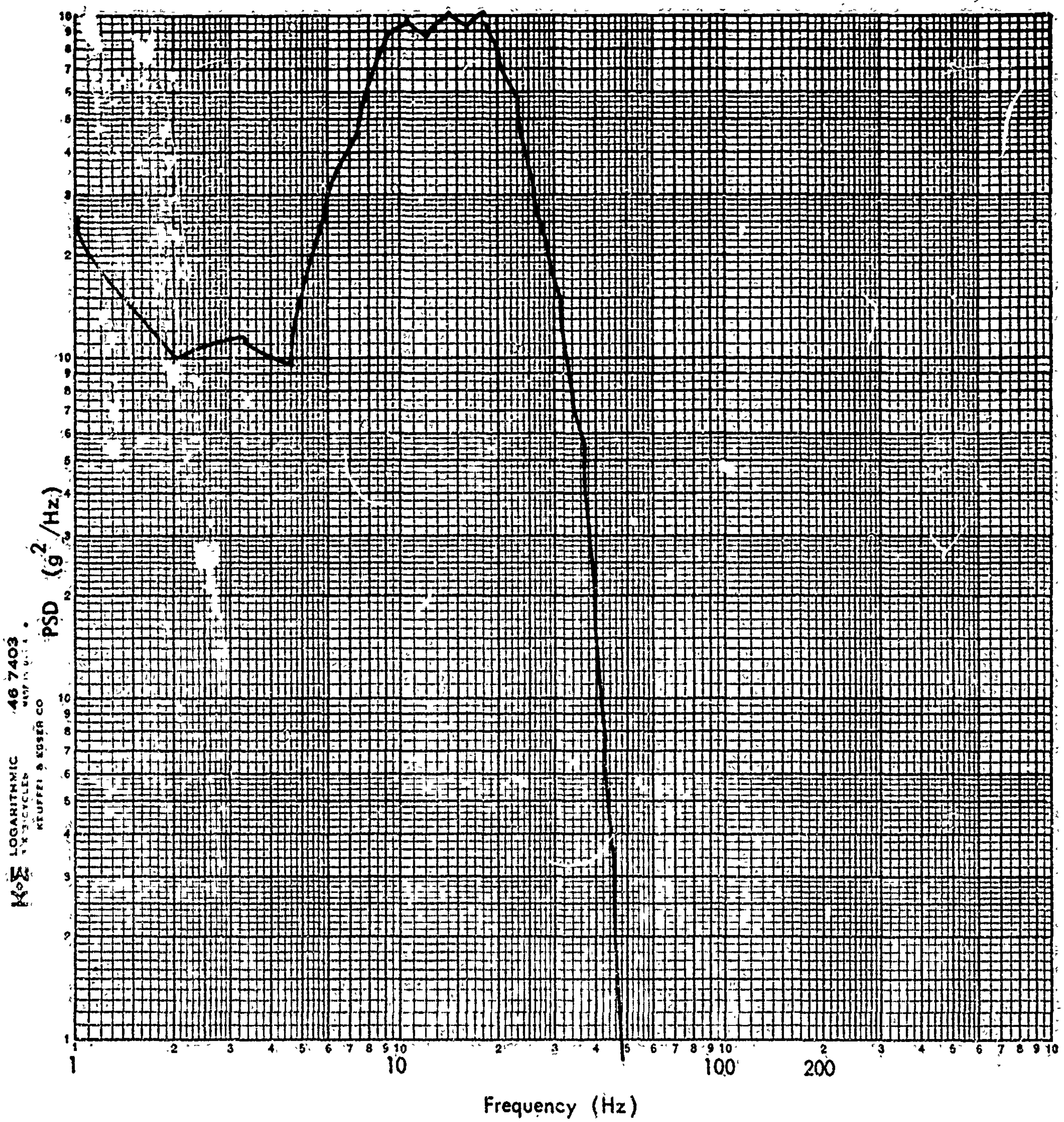
TEST RUN NO. 3 START

Figure 15. Power Density Spectrum for 0.1 g^2/Hz Level Testing

FULL SCALE LEVEL (g / Hz)

.01 ☐ 0.1 ☐ 1.0 ☒ 10 ☐ 100 ☐

J/N
Page
Date 6-11-73



CUSTOMER USCG AXIS VERT

SPECIMEN Fuel Vapor Detector LOCATION NO. CONTROL

S/N TEST RUN NO. 4 START

Figure 16. Power Density Spectrum for 0.3 g^2/Hz Level Testing

TABLE XII. DETECTOR RESPONSES AFTER VIBRATION TESTING

Test Level & RMS Accel.	Test Length	Specimen	Detector Response and Condition
$0.01\ g^2/Hz$	1 hr	VD-1	Green "safe" light blinks during saturation test. Loose light bulb.
1.76 g rms		VD-2	Saturation test - o.k.
		VD-3	Meter mounting has vibrated loose*
		VD-4	Saturation test - o.k.
		VD-5	Saturation test - o.k.
$0.03\ g^2/Hz$	1 hr	VD-1	Self-test did not function. Bright blue "hold" light on during saturation test. No indication of danger or explosive condition.
3.7 g rms		VD-2	Saturation test - o.k.
		VD-3	No alarm or meter indication of vapor during saturation test. Alarm did not function during self-test.
		VD-4	Alarm on but meter does not indicate explosive condition during saturation test.
		VD-5	Saturation test - o.k.
$0.1\ g^2/Hz$	25 min.	VD-2	Would not self-test.
5.9 g rms	1 hr	VD-5	Saturation test - o.k. Voltage regulator found loose in base and re-tightened at 25 min. into test.
$0.3\ g^2/Hz$ 11.5 g rms	24 min.	VD-5	Voltage regulator tube had broken

* Tightened screws

At the conclusion of the vibration tests the detectors were inspected for physical damage. In VD-1 the screw retaining the back part of the alarm assembly was found to be loose and the alarm broken. Figure 17 shows this damage and the corrosion which appeared on the bulb holders during the humidity tests. Figure 18 shows a broken lead on the terminal strip in VD-2. Figure 19 is a view of the meter for VD-3 showing the final permanent 1/2 scale reading and Figure 20 shows the broken alarm. Figure 21 is a view of the mounting base for the voltage regulator tube of VD-5 showing a broken lead and indicating that the voltage regulator tube had broken completely off at the base. No visible damage was found for VD-4.

8.0 DISCUSSION OF RESULTS

Of the five detectors tested VD-5 performed much better than any of the other four. It always indicated an explosive condition when such existed. The highest % LEL necessary to make it indicate an explosive condition was 80% LEL after it had been subject to the ten day humidity test. If anything, it might be judged a little too sensitive. It was also the instrument that withstood the highest level vibrational testing before suffering physical damage. It also appeared to be the most solidly constructed unit with the weakest component being the voltage regulator tube assembly.

Unit VD-3 exhibited the worst performance of the five units. Even in the initial operational test (Table IV) the unit did not give a meter reading of "explosive" at 100% LEL although the alarm did sound. Again, it was among the first of the units to suffer physical damage during the shock and vibration testing. It was noted that the alarm always sounded while the meter still read "safe." This might be confusing to a boat operator.

VD-1 displayed somewhat erratic behavior with respect to the operational tests. It did not indicate an explosive condition in its initial operational test (Table II) nor after the high temperature and humidity tests. It did indicate an explosive environment after the low temperature test and was acceptable in all of the saturation tests after shock testing and the lowest level of vibration testing.

Figure 17. Damage to Test Specimen VD-1

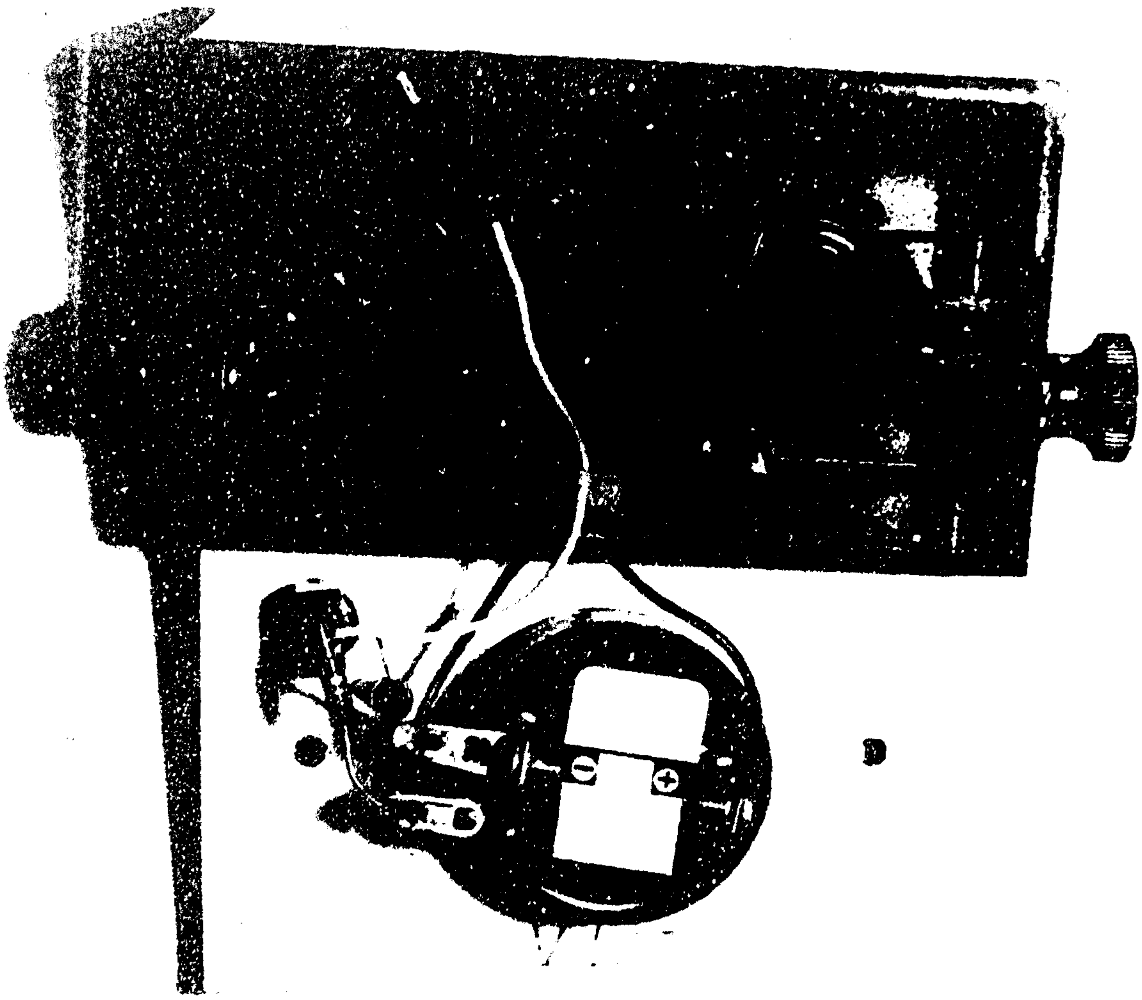


Figure 18. Damage to Test Specimen VD-2

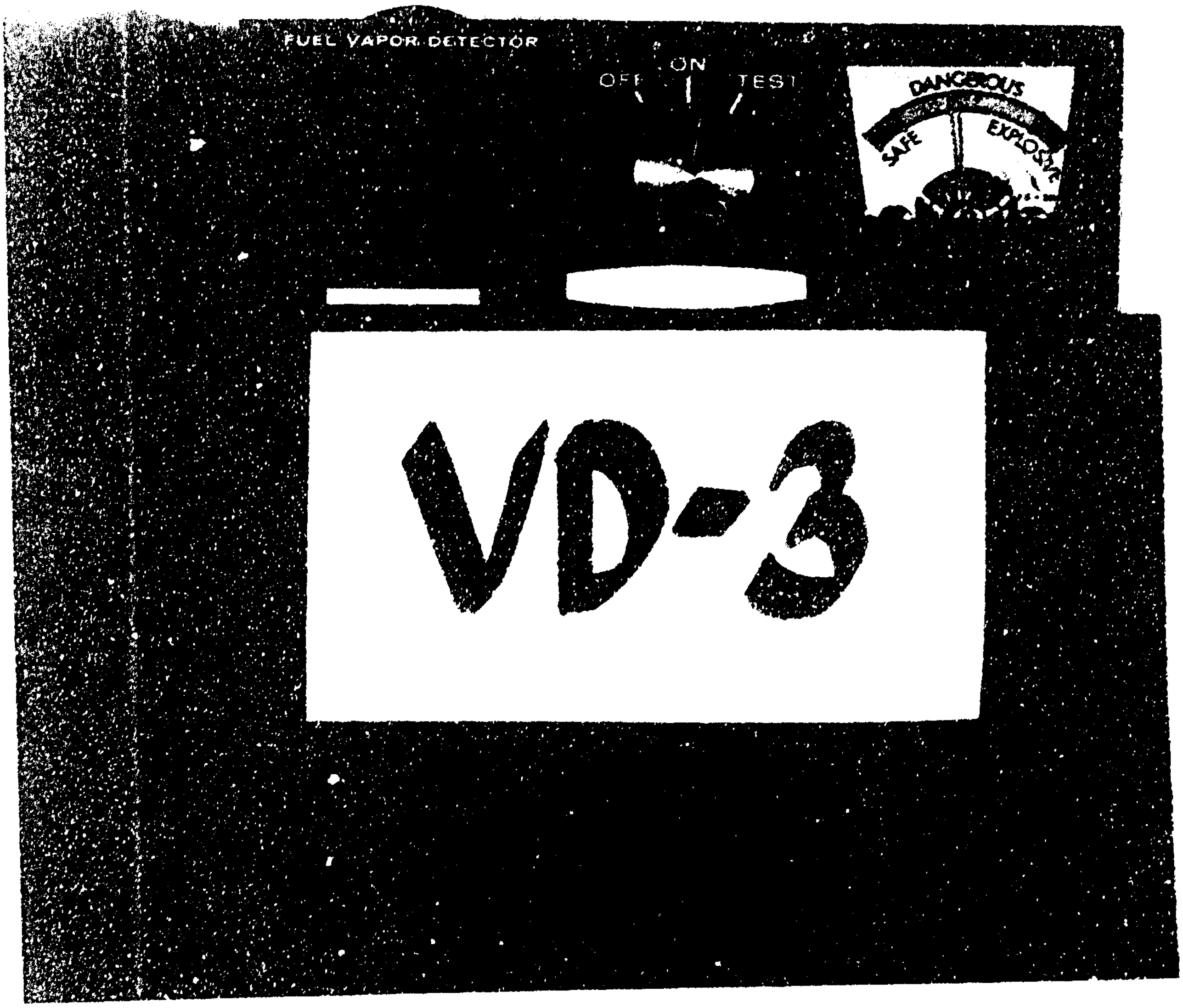


Figure 19. Permanent 1/2-Scale Meter Deflection — Test Specimen VD-3

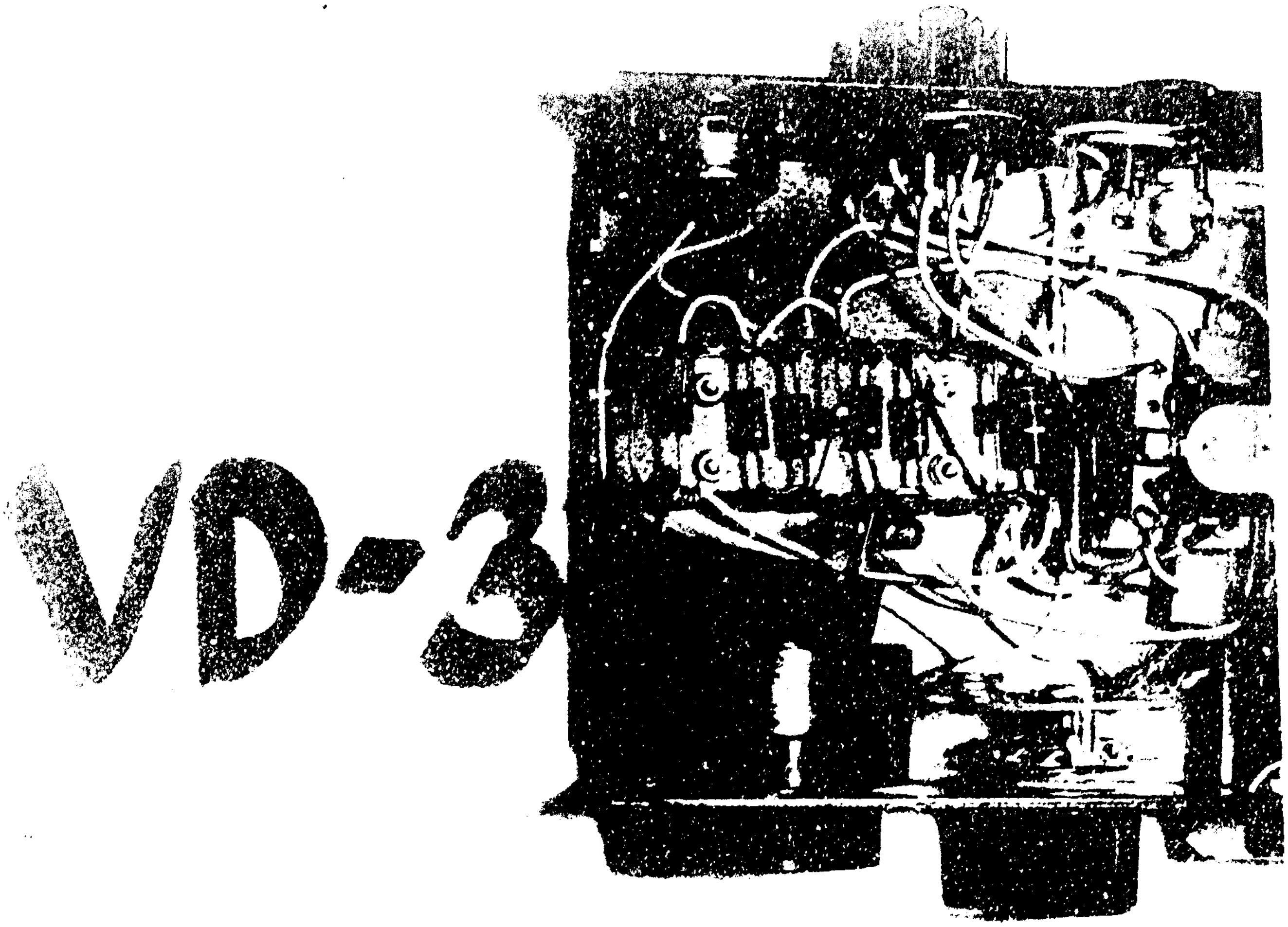


Figure 20. Internal Damage to Test Specimen VD-3

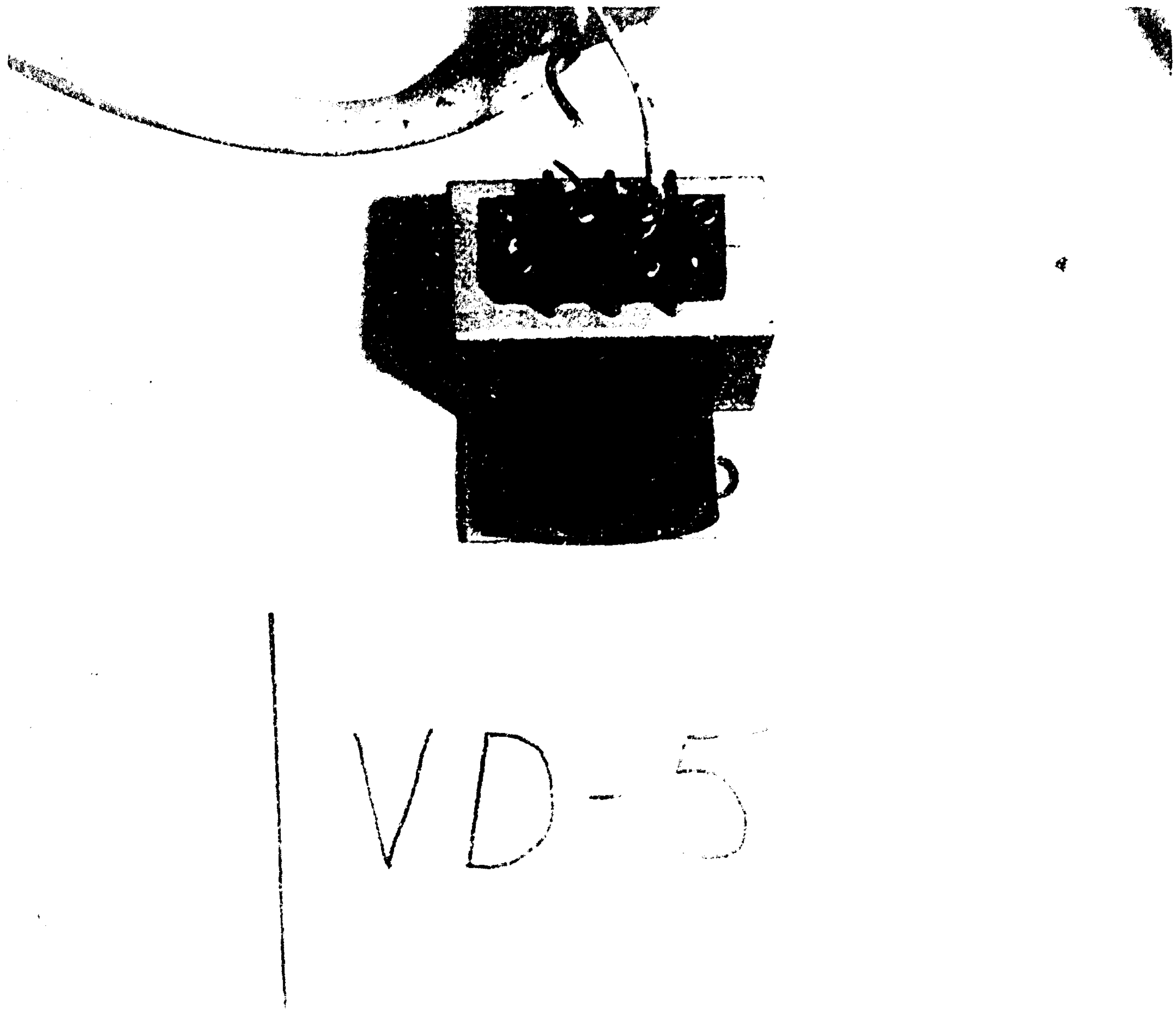


Figure 21. Damage to Test Specimen VD-5

APPENDIX

SHOCK AND VIBRATION DATA SHEETS

REFERENCES

1. "Fuel Vapor Detectors – Evaluation Plan," Interim Report – Task Order 10, USCG Project No. 735408. December 8, 1972.

2. "Fuel Systems Standards Analysis Development Report," Dept. of Trans., USCG R and D Project No. 735504, Appendix F, Section 2.8.

APPENDIX

SHOCK AND VIBRATION DATA SHEETS

INSTRUMENTATION EQUIPMENT SHEET

Date 6-8-73 Job No. 58210 Test Area DYNAMICS

Technician V. GILLIAM Customer USCG Type Test VIBRATION

No.	Instrument	Manufacturer	Model No.	Serial No.	Wyle or Gov't No.	Range	Accuracy	Calibration On	Calibration Due
1	ACCELEROMETER	ENDEVCO	2272	NA46	F-1412	1000g	±5%	3-21-73	6-21-73
2	CHARGE AMP	DYNAMICS	7302AH	NA	F-1610	500g	±2%	12-26-72	6-26-73
3	RANDOM CONSOLE	LING	RS0E80	NA	93751	2KHZ	±1DB	5-21-73	6-21-73
4	XY RECORDER	HEWLETT PACKARD	7044A	NA	95297	.5MV/IN to 10V/IN	±.2%	6-7-73	9-7-73
5	DUAL LOG CONVERTER	SPECTRAL DYNAMICS	SD-12	NA	95132	80db	±.5db	3-19-73	6-19-73
6	OSCILLOSCOPE	HEWLETT PACKARD	122AR	NA	80581	.01 to 10V/CM	±5%	5-11-73	8-11-73
7	VTVM	BRUEL KJAER	2416	NA	80270	.01 to 1000V RMS	±2%	5-9-73	8-9-73
8	TIMMER	STANDARD	S-60	NA	80283	60MIN	±1SEC/HR	1-9-73	7-9-73
9	VIBRATION EXCITER	LING	A246	NA	6378	5HZ to 2KHZ	NA	NA	NA

Instrument Test Engineer S. De Lucchi

Checked & Received By T. Nottingham

WYLE LABORATORIES

INSTRUMENTATION DATA SHEET

Recorder No. X Y Recorder Date 6-8-73 Axis Vert Setup USCG J/N 58210

Accel. S/N	Amp. Ch.	Galvo Tape	Insert q Pk	Volt q Rms	Location	Comp. Ch.	Run # 1-4 mv/g	Run # 1-4 g/in.	Run # mv/g	Run # g/in.	Remarks
NA46	97	—	12.8		CONTROL		10	NA			
		—									
		—									
		—									
		—									
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W 322

WYLE LABORATORIES
INSTRUMENTATION LOG SHEET

JOB NO. 58210 LOG PAGE NO. ______ OF ______

CUSTOMER USCG TEST ENGINEER ______

DATE	TIME	REMARKS (Include Run Number, Part Changes, Shift Changes and all other pertinent data)
6-8-73	1100	SET UP XY RECORDER TO RECORD RANDOM VIBRATION
		ON USCG FUEL VAPOR DETECTOR VERT AXIS
	1310	RUN # 1, RANDOM .01 G^2/HZ VERT AXIS 1HR
		MADE X Y PLOT OF THE CONTROL
		RUN # 2, RANDOM .03 G^2/HZ VERT AXIS 1HR
		MADE XY PLOT OF THE CONTROL
		RUN # 3, RANDOM .1 G^2/HZ VERT AXIS 1 HR
		MADE X Y PLOT OF THE CONTROL
		SHUT DOWN AFTER 30 MIN IN TO RUN.
6-11-73	0605	RESTART RUN # 3 WITH 30 MIN TO GO.
		MADE XY PLOT OF CONTROL.
		RUN # 4, RANDOM .3 G^2/HZ VERT AXIS 1HR
		MADE X Y PLOT OF CONTROL. BROKE SPECIMEN AFTER 24 MIN.